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Azzurra Robot Team - ART

ART

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Abstract. *Azzurra Robot Team (ART) is the result of a joint effort of six Italian research groups from Univ. of Genova, Politecnico Milano, Univ. of Padova, Univ. of Palermo, Univ. of Parma, Univ. Roma "La Sapienza", and Consorzio Padova Ricerche which has provided resources and a set up of the soccer field in its Center in Padova. We have developed the team within the framework of the RoboCup Italia Project, with the aim of education and training of students in the subjects related to the design of autonomous mobile robots, of developing new research ideas and foster the development of larger projects in this field in Italy.*

1 Azzurra Robot Team

Azzurra Robot Team (ART) is the National Italian Team for F-2000 RoboCup league, developed within the framework of the RoboCup Italia project, and for RoboCup-99 ART is formed by six academic groups and the Consorzio Padova Ricerche. The goal of the project is to exploit the expertise and ideas from all groups in order to build a team where players have different features, both hardware and software, but retain the ability to coordinate their behaviour within the team. Therefore, the ART team includes several types of players, that are built on top of two hardware bases: baseART and Mo^2Ro.

Below we provide a short description of the two basic architectures, and subsequently we shall address each type of player. Finally we shall address the research problems that are tackled by every unit of the team.

2 Robotic bases

Presently, we are using two robotic bases: BaseART and Mo^2Ro which are described below.

2.1 BaseART

BaseART was developed in preparation to the 1998 RoboCup by assembling several out-of-the-shelf, low-cost components, with the goal of keeping it very standard in terms of hardware and, therefore, easily extensible with new devices.

The first building block is constituted by the Pioneer 1 mobile basis and the second is constituted by a conventional PC, running LINUX, for onboard computing. We have reached a compromise between weight and power consumption, where the player has enough autonomy to play games.

The third component is constituted by a wireless high bandwidth connection that we consider necessary to have a development environment that allows the programmer operating on a standard platform (connected to the robot) to obtain accurate information about the situation onboard. The wireless connection supports also the exchange of information among the players, but it is not currently used to transfer raw data among the players.

The fourth component is the vision system which is constituted by a low-cost frame grabber based on the BT848. At Robocup 99 we have used a Sony XC-999P color camera with about 100^o aperture angle. The cameras are positioned differently on different types of players.

The fifth component is a kicking device driven by air pressure, with two actuators that can enable the player to kick left or right or straight (when both kickers are activated at the same time).

2.2 Mo^2Ro

Mo^2Ro is a *Mo*dular *Mo*bile *Ro*bot base designed and implemented at Politecnico di Milano Artificial Intelligence and Robotics Lab. When we decided to build it, we needed a general purpose robot to match the Robocup specifications, but also the needs of other projects in our lab. Mo^2Ro can run up to 60 cm/sec, and may have more then 40 kg as payload. The hardware is functionally layered, and any module can be easily added or removed. At the first level, we have mounted, in the different implementations of Mo^2Ro: a sonar belt, bumpers, encoders, and different vision sensors; among these: two different types of omnidirectional sensors [3], and a camera mounted on top of a 5 DOF arm. Among the actuators that we have adopted up to now we have two DC motors for movement, a kicker, and the arm. On the second layer, control and data acquisition can be done either by commercial or by home made cards, including one based on a Motorola 68HC12 fuzzy chip. Low level control may be implemented by fuzzy rules either on the fuzzy HW, or on the PC. The third layer consists of behavioral and data interpretation modules, implemented in the ETHNOS [12, 11] real time architecture.

3 Goal keepers

In the ART team we have developed two different kinds of goal keepers, TinoZoff which is described below, and Saracinescu, that was used during 1998 championship [5], but was not available for Robocup-99.

3.1 Tinozoff

The physical layout of the goalie is considerably different from the other players' structure. This goalie has a vision system based on two wide-angle cameras placed on top of it, having an aperture angle of about 70^o vertically and 110^o horizontally. This allows the robot to extend its field of view to over 200^o, considering that the fields of view of the two cameras overlap by about 20^o in the central region right in front of the goalie.

As for its cinematics, the two driving wheels are located in the middle of the chassis, one on the front and the other on the rear. This makes translational movements more precise and accidental turns less likely. Balance is ensured by a pair of spheres, on which the robot leans, that are positioned along an axis at 90^o to the wheel axis, and passing through its center. Turning is possible because the two wheels can be operated independently. Just ahead of the front wheel is a pneumatic kick device, whose air hangs just above.

The vision system and the self-localization method developed for it are described in [1].

4 Middlefield players

In the ART team we currently have three types of middelfield players.

4.1 Ronaltino-Tottino

Ronaltino-Tottino is a middlefield player developed on BaseART. Its essential features from the hardware viewpoint are: a specialized vision system with a camera rotating on 360^o, a compass, and infrared sensors to enable the kicking when the ball is close to the kickers.

The control system of this player is designed on top of SAPHIRA, an environment developed to implement the robot control both in terms of actions, realized as programs in the Colbert language, and in terms of fuzzy behaviours, that are executed by a fuzzy controller. In [7] we discuss our experience in the design of the control system for this player based on fuzzy rules. To overcome some of the difficulties encountered in the programming of robot behaviors in the Robocup scenario we have developed several tools to support the designer in the debugging and experimental activities.

We also implemented several self-localization methods relying on the vision-based recognition of the goals, on the information coming from the compass and on the vision-based analysis of the lines in the field [8]. We have compared them trying to identify the conditions under which each source of information for localizing the player is reliable.

4.2 Relè, Bart, Homer

Relè, Bart and Homer are middlefield players, developed on baseART, provided with different settings for the kicking device and characterised by a novel software planning and control architecture based on the ETHNOS real-time programming environment. ETHNOS exploits the Linux RT multithreaded operating system and provides additional support from different points of view. From the communication perspective it supports and optimises transparent inter-robot information exchange and co-ordination across wireless media. From the runtime perspective it provides support for the real-time execution of periodic, sporadic and background tasks (called Experts), schedulability analysis, event handling, and resource allocation and synchronisation. From the software engineering perspective it provides support for rapid development, platform independence and software integration and re-use.

The whole set of software module for controlling the players has been developed over the ETHNOS' Kernel. Besides its use for managing communication with Pioneer hardware facilities, ETHNOS' Kernel has been used for developing several basic behaviors (Ball-Searching, Ball-Reaching, Ball-Shooting, Ball-Bringing) as well as the vision module. ETHNOS' Kernel has been selected because of the flexibility of its architecture, allowing the real time scheduling of both occasional Experts, that are conditionally activated, and periodic Experts. Thus, Vision Experts, and Map Building Experts are realized as Periodic Experts, whereas an arbitration module over basic robot skills can usefully exploit the fast real time decision making capabilities of a suitable Occasional Experts.

4.3 Rullit

Rullit is implemented on a Mo^2Ro base. Its design is centered around the omnidirectional vision sensor we have implemented for Robocup. It consists of a mirror studied to exploit at best all the camera definition both in the neighborough of the robot and at a large distance: the ball corresponds to a reasonable number of pixels from 10 to 400 cm all around the robot. The vision system is implemented mimicking some natural mechanisms for fast tracking and color interpretation: we have distances from all the visible, classified objects at a rate higher than 20 frames/sec. This makes it possible to implement behaviors and strategies that take advantage of the knowledge about most of what surrounds the robot. For instance, it can move without problems also backward at a high speed, or it can take a position while monitoring ball and other robots also not in front of it. A self-localization module also has enough reliable information to provide an approximate, but satisfactory extimation of the position in most of the situations. Behavior modules are implemented to face the different situations, including those produced by the current rules about charging. A fuzzy low-level control system provides reliable actuation to the fuzzy behaviors modules.

5 ART Research perspective

Research is a major goal of all the members of the ART team. This is demonstrated by the specific contributions presented at the Robocup Workshop

[2, 4, 8, 11]. It is worth emphasizing that the need of coordinating heterogeneous soccer players has lead to interesting results, by practically showing the feasibility of coordination in a fully distributed, heterogeneous multi-robot scenario. In the following we report on the research perspective of each group in the team.

Univ. Genova

The research in the software control architecture carried out in ART has different goals which are tightly tied together: (1) the study and development of a hybrid cognitive model suitable for a set of interacting autonomous robots, (2) the analysis of the architectural and computational requirements of an autonomous robot, (3) the development of a suitable programming environment for multi robot applications.

From the cognitive model perspective we aim to better understand the relationship between different forms of representation and reasoning starting from a reference model we recently proposed [10]. In this model symbolic, diagrammatic and procedural representations and/or activities are integrated in a non-hierarchical framework. Different hierarchies are formed dynamically depending on the task that the robot has to perform. For example for a complex assembly operation symbolic representation and planning will drive the activity of motion control reactive procedures; for autonomous navigation tasks, diagrammatic and procedural knowledge will drive the robot behavior while the symbolic activities are only responsible of data interpretation and symbol extraction.

From the software architecture perspective we intend to study what support is required and suitable to allow the robot to respond in real time to the changes in a partially structured environment. In particular our research will focus on scheduling algorithms that take into account the heterogeneity of the set of tasks that have to be executed: periodic/sporadic, hard real time/soft real time/any time/background, predictable/non predictable, etc. These algorithms will be integrated and experimented on using the ETHNOS [12] programming environment.

Politecnico Milano

Our aim was to implement a reliable machine where the competences present in our Lab, and in the whole team, could merge to realize a large set of tasks, including Robocup. We have faced all the problems related with the development of such a machine: hardware (both electronical and mechanical), operating system, sensors (including vision), low-level fuzzy control, behaviors, strategy, communication, and learning. Most of this activity up to now was aimed at building a robust base to experiment the higher level aspects. We have implemented our behaviors as modules activated by two sets of fuzzy preconditions: the *cando preconditions* enable the behavior, and the *want preconditions* give the amount of motivation for it. Moreover, we have two parameters: the static and the dynamic *relevance*. The first implements a priori a partial ordering among behaviors, the second a partial ordering modified according to the situation, and used to implement strategies. The behavior with the highest *triggering level* (a composition of these four factors), is activated, and its actions done. We have a winner-take-all activation, instead of a composition of proposed actions typical of fuzzy systems, since this gives more coherence to behavior selection. We have also implemented a reinforcement learning system that interprets the model built from the sensorial input, and identifies and classifies the actions taken by the other robots. By acting on the dynamic relevance, this system learns the best behavior for each situation, and makes Rullit to adapt its behavior to the opponents.

Univ. Padova

Coordinating the whole soccer-robot team is a fundamental problem in the multi-robot research field. A sound arbitration mechanism, for both single and collective actions, is the base for an appropriate coordinated performance of behavior-based autonomous systems. To approach correctly the problem of controlling a multi-robot system, we have also to consider the interference among robots as a potential to inhibit, or limit, the behavior of each single robot in the case of resource competition. This potential increases with the number of robots, eventually causing the degeneration of global performance, and forcing the use of social rules. In the soccer robot case, a further difficulty arises, due to the simultaneous presence of several playing agents in the same environment. Coordination among robots may arise when single individuals plan complementary actions, and when some kind of prediction is available.

A second problem is given by the possibility of using a different kind of co-operation among robots, namely the implicit one. While passing intentional information is realized sending voluntarily explicit coordination messages to the other agents, implicit cooperation is realized by looking at the external behavior of the other agents, without any transmission of information. We have considered, the case where a set of actions, performed by a single robot to achieve its own goal, affects the world and helps other robots to achieve their goal. As the form of communication, we considered only the observing of the behavior of other robots, that is based on affecting the environment rather than on passing explicit messages. Thus, an interesting example of emergent cooperative behavior arises from this form of communication [9].

Univ. Palermo

The main contribution of the unit of Palermo is the development of a system for the robust segmentation of the color images acquired by the camera of the ART robot.

Although the colors of the objects in the RoboCup framework are clear and well defined, several disturbing conditions arise during the competitions. The light conditions of the field vary during the day; the persons and the other robots generate unexpected shadows effects; Different game fields may be characterized by similar but not equal colors.

We are investigating a novel method based on feed-forward neural networks that learn to recognize the hue range of meaningful objects. A neural network does not require the exact knowledge of the statistical distribution of input items, as it generates an internal representation of input data distribution by a suitable learning phase.

First experimental results showed that the approach is effective and robust with respect to environmental conditions, shadows and illumination variations. Although this method is tailored to the RoboCup experimental framework, we claim that it is an effective intermediate-level step in generic image interpretation tasks where the color is a meaningful descriptor.

Univ. Parma

In designing the goalie, three main problems had to be tackled: (1) Object detection and motion estimation; (2) Self-localization and repositioning; (3) Task planning.

Object detection is performed through a color-based segmentation algorithm. Such an algorithm returns the position of the ball and of possible other players occupying the goalie's field of view for each frame received from the cameras. By comparing two subsequent frames and taking the robot motion into account, it is possible to estimate the instantaneous speed and direction of the ball. As it is not possible to acquire the images coming from the two frame grabbers at the same time, there is a switching strategy based on the detection of the ball. When the ball is not detected by either of the two cameras, the camera from which the image is acquired is switched. When the ball is detected by one of the two cameras the image is acquired from such a camera until it enters the overlap region of the two fields of view. At that point a switch to the other camera is performed.

Self-localization and re-positioning are based on an algorithm which detects the lines of the penalty area and infers the goalie's position through a comparison between the images acquired by the two cameras. The goalie's area front line is first detected in the two frames. If the goalie is aligned with such a line, the two resulting images are symmetric. If the goalie is rotated, such a symmetry is lost.

Univ. Roma "La Sapienza"

The main focus of the reasearch of the group at DIS, "La Sapienza" is on the design of cognitive mobile robots, namely robots where a deliberative layer including an explicit representation of the robot's knowledge on the environment is added, with the aim of increasing the robot's performance in accomplishing complex tasks. Our approach to the design of cognitive mobile robots insists on the view that a global design of the layers of the architecture is necessary to achieve the desired performance.

Consequently, we have developed both a set of basic behaviours to provide the robots with individual skill and we are currently working at identifying the behaviour structures that have to be executed in order to achieve a given goal in a given situation. Such structures embody concurrent actions, sensing actions and take into account of the cooperation among players.

To this end we are extending the framework proposed in [6] so to enable the robot to plan the actions to achieve a given goal, negotiate the actions to be executed with the team mates, and activate the behaviour structures that drive the actions of the robot.

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